ON FOULING AND BORING ORGANISMS AND MORTALITY OF PEARL OYSTERS IN THE FARM AT VEPPALODAI, GULF OF MANNAR

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ABSTRACT

Pearl oysters of the species *Pinctada fucata* were reared in the Gulf of Mannar, off Veppalodai, by raft culture, for production of cultured pearls. Observations revealed a heavy growth of fouling and boring organisms on the pearl oysters, necessitating frequent shell-cleaning operations. Barnacles, bryozoans and spats of molluscs, *Avicula* and *Crassostrea*, were the significant fouling organisms, and a seasonal trend was observed in their dominance. The spionid polychaete *Polydora* and the clionid sponge *Cliona celata* were the important boring organisms causing considerable damage to the shells. Infection by polychaetes, as observed from the blisters and tumour-like growths on the inner aspect of the shells, was 78.4% and by sponge 20.7% among the shells examined.

During the period from January 1973 to December 1974, the monthly rate of mortality of oysters varied from 0.9% to 27.5%. This generally followed the trend of fluctuations in average volume of fouling and barnacle load on the oysters. Two peaks of mortality were observed, which coincided with the northeast and southwest monsoons respectively. Possible remedial measures against some of the fouling and boring organisms have been indicated.

INTRODUCTION

Experiments on pearl culture were taken up at Veppalodai, near Tuticorin, in 1972, which resulted in the successful development of spherical cultured pearls for the first time in India (Alagarswami 1974*a*). In the course of the experiments, it was noticed that fouling was a serious problem in the farm (Alagarswami and Qasim 1973). Similarly, Kuriyan (1950) had observed a dense settlement of organisms on the pearl-oyster cages at Krusadai island, in the Gulf of Mannar. In the pearl-culture farms of Japan, both fouling and boring organisms affect the pearl oysters and these have been studied in great detail (Nishii 1961, Mizumoto 1964, Yamamura *et al* 1969). The results of the investigations, carried out at Veppalodai from January 1973 to December 1974, on the fouling and boring organisms and their adverse effects on the pearl oysters, are presented here.

MATERIAL AND METHODS

The living pearl oysters (*Pinctada fucata*) themselves formed the habitat of the fouling and boring organisms in the present study, and no panels were used. The oysters were grown by raft-culture techniques (see Alagarswami and Qasim 1973). The rafts were located about 1.5 km from the sandy shore of Veppalodai, north of Tuticorin (Gulf of Mannar). The oysters were arranged in sandwich-type frame nets of 60cm length and 40cm breadth, partitioned into 5 equal sections. The frame nets were suspended from the raft by synthetic ropes at a depth of 3.5 m, where the depth of the sea was 4.5 m. In the suspended position, the oysters rested vertically with their hinges down. The sea bottom in the farm site was fairly hard with a mixture of sand, mud and broken pieces of shells and corals.

Data on fouling and boring organisms living on the pearl oysters were recorded during the periodical shell-cleaning operations. There were, in all, 117 frame nets with oysters in the farm during January 1973 to December 1974. Most of the oysters underwent 8 to 10 cleanings during the period. The frame nets were brought to the laboratory at Veppalodai in lots of about six. One oyster from each of the 5 sections of the net was taken out at random and was scraped clean of all the fouling organisms. The volume of the material collected from 5 oysters was estimated by displacement method. The intensity of fouling was graded as low, medium, heavy, very heavy and extremely heavy, based on a volume-scale of 0-20 ml, 21-40 ml, 41-60 ml, 61-80 ml and over 80 ml, respectively, of fouling material on 5 oysters. The average volume of fouling organisms per oyster for different durations of the stay of oysters in the farm was calculated from these data for each month of observation. The fouling organisms were sorted and identified to the extent possible. Since barnacles were found to be the most dominant single group they were counted irrespective of their size and the average number of barnacles per oyster was calculated. The average surface area of both the valves of the farm oyster was about 55 sq. cm.

The extent of damage caused to the shells by the different boring organisms was recorded. The polychaetes were collected after narcotising them along with the pearl oysters, whereas other organisms were collected by digging them out of their tunnels or perforations. The rate of mortality of pearl oysters was calculated as percentage of the number of dead oysters out of the total number examined.

FOULING ORGANISMS

In this investigation emphasis was laid on the dominant groups of the fouling complex and their measurable effect as reflected in the rate of mortality of the oyster stock in the farm. Hence, setting aside the numerically fewer and the microscopically smaller organisms which are nevertheless significant, for a subsequent detailed investigation, an attempt was made to study the more numerous and larger organisms which contributed to the mass of fouling. Barnacles, bryozoans and molluscs were the dominant fouling organisms in the order of importance, tunicates, decapod crustaceans, hydroids, anthozoans, etc. forming the less significant ones. Some features of fouling relating to barnacles, bryozoans and polychaetes are illustrated in Pl. I, Figs 1-4.

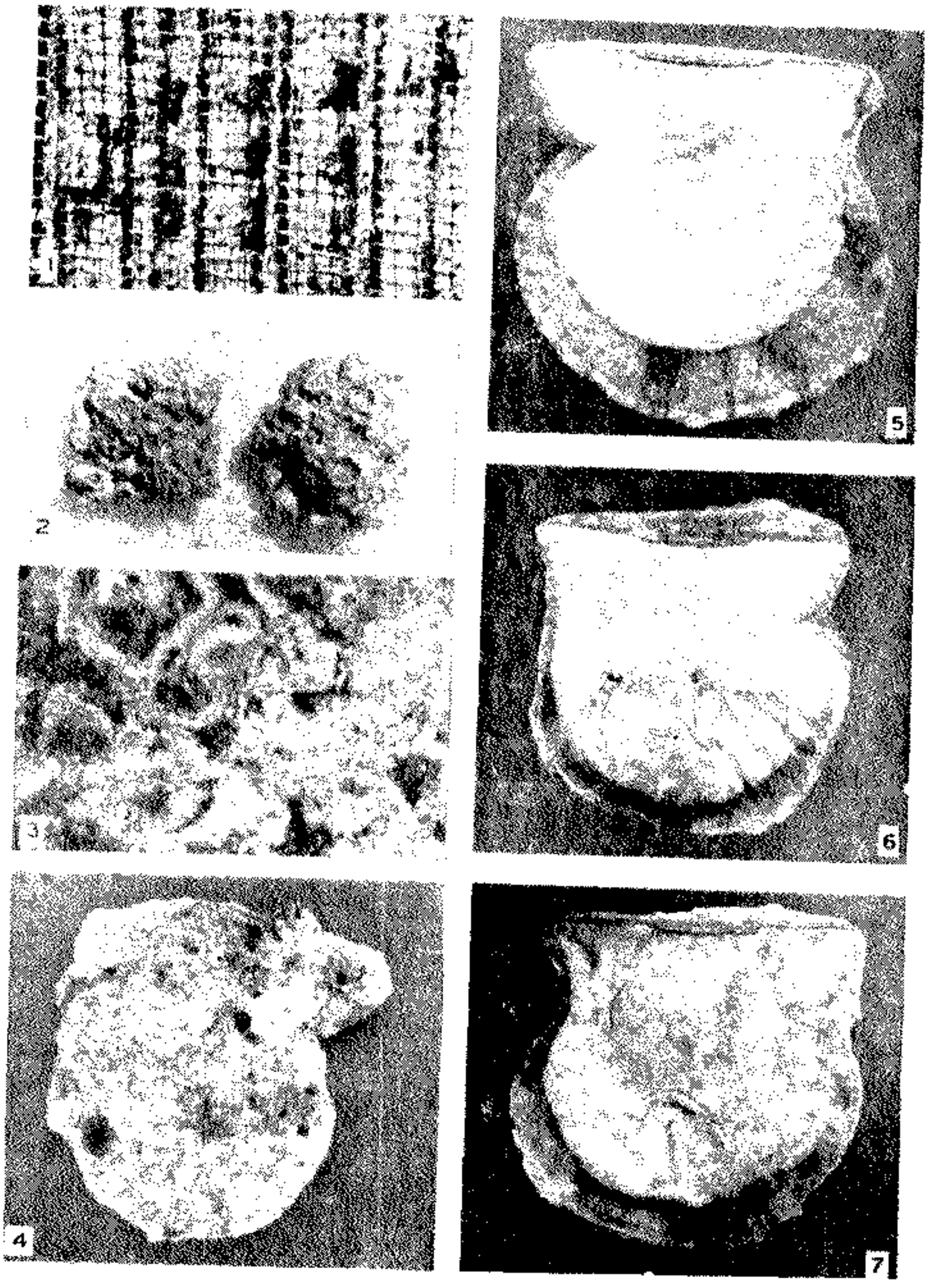
Barnacles: The cirripede *Balanus amphitrite variegatus* was the most important constituent of the fouling community. *B. a. communis* was noticed in fewer numbers. Though the barnacles were present throughout the period, large-sized ones dominated during July-September. The barnacle load was generally taken as the criterion for timing the shell-cleaning operations in the farm.

Bryozoans: Next to barnacles, the bryozoans were the common fouling organisms. The encrusting forms *Membranipora* sp., *Thalamoporella* sp. and *Lagenipora* sp. were met with almost throughout the year. *Watersipora* sp. and *Bugula* sp. were particularly dominant in February and June 1974, spreading all over the frame nets.

Molluscs: *Avicula vexillum* was the most numerous of all the fouling organisms during April-June 1973. The size range of this species was from less than a millimeter to 8.8 mm. There was such a luxurious growth of *A. vexillum* that almost the entire surface of the nets was covered by a thick, green, carpet-like growth. The species was totally absent from July 1973 to April 1974. In May 1974, settlement of *A. vexillum* was again noticed, but in far fewer numbers. They disappeared in the second fortnight of June 1974. In very young stages, their resemblance to the spat of pearl oysters was striking. Hornell (1922), noting this resemblance, called the spat of *Avicula* as "false-spat". *Modiolus metcalfei*, though only occasionally found, occurred in fairly large numbers in July 1974. The size range of this species was 4.0-9.2 mm.

The spat of edible oyster *Crassostrea* sp., in the size range of 5.4-23.5 mm, were noticed in large numbers on the pearl oysters and frame nets during May-June 1974. The edible oyster was not recorded before in the farm. Spat of pearl oysters of at least three species, *Pinctada fucata*, *P. chemnitzii* and *P. sugillata* were noticed almost throughout the year. However, their occurrence was high during May-July 1973 and June 1974. In other months, only a few could be collected. Alagarswami and Qasim (1973) gave the size distribution of *Pinctada* spat collected from May to July 1973. Although they formed part of the fouling complex, the settlement of pearl-oyster spat in the farm was significant in mother-oyster culture for the production of cultured pearls (Alagarswami 1974*b*).

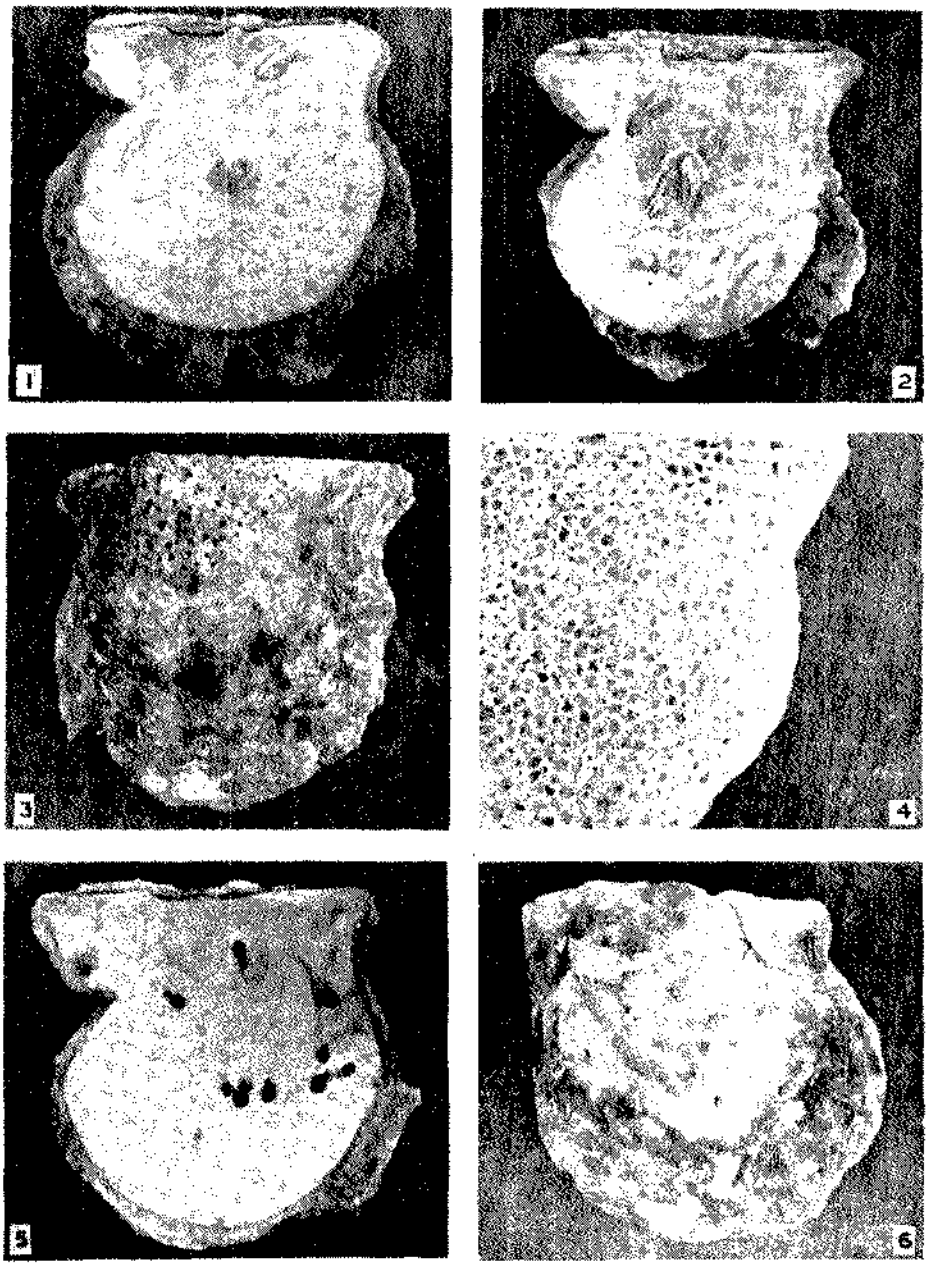
Tunicates: Simple ascidians *Ascidia depressiuscula* and *Dicarpa* sp. and compound ascidian *Diplosoma* sp. were recorded almost throughout the year. The ascidians were found in large numbers during October-December when barnacles were fewer. The colonies never grew large enough to engulf the oysters because of frequent cleaning of the shells.



Features of fouling and boring on pearl oysters –

1. Moderate fouling on the frame net and oysters; 2. Heavy fouling of barnacles on the oysters; 3. Fouling of polychaete *Hydroides* sp.; 4. Fouling by bryozoans and a solitary coral; 5. A centrally located blister on the inner aspect of the shell; 6. A number of marginal blisters; 7. U-shaped blister; blisters at figures 5-7 caused by *Polydora* sp.

(*Facing P. 12*)



Features of fouling and boring on pearl oysters —

1. A tumour-like blister near the adductor impression; 2. Compound blisters caused by boring polychaetes; 3. Early stage of attack on the shell by *Cliona celata*; 4. Advanced stage of attack by the sponge; 5. Holes on the shell bored by *Martesia*; 6. Shallow groove below the hinge line and at the centre of the shell made by *Sphaeroma*; a few external openings of tunnels of polychaetes are also seen.

(*Facing P. 13*)

Decapod crustaceans: Several genera of crabs, including *Thalamita, Charybdis, Matuta, Porcellana* and *Pinnotheres,* were found both on the pearl oysters and the frame nets, especially among the hydroid and algal growths. Alphaeids and postlarvae and juveniles of *Panulirus* sp. were also occasionally found on the frame nets.

Hydroids and anthozoans: Hydroid colonies were particularly seen during October-December, along with algal growth. Species of *Companularia, Obelia, Sertularia, Abietinaria* and *Lytocarpus* were the common hydroids. Solitary and colonial sea anemones (*Paranemonia* sp. and *Bunodactis* sp.) and alcyonarians (*Sarcophytum* sp. and *Clavularia margaritiferae*) were occasionally met with. A solitary coral of dark brown colour was found rarely.

Others: Besides the above significant groups, the fouling complex was composed of a large number of gammaridean and other amphipods, isopods (*Sphaeroma* sp.), pycnogonids (*Nymphon* sp.), sponges (*Siphonochalina communis*), encrusting tubicolous polychaetes (*Hydroides* sp.), nematodes (*Enoplus* sp.), polyclad worms, opisthobranchs, *Pinna* shells, egg capsules of squids, crinoids and algae (*Gracilaria edulis, Boergesenia forbesii, Codium tomentosum, Ceramium* sp. and *Cladophora* sp.). While amphipods, isopods and sponges were noticed throughout the period, other groups occurred in large numbers only in certain months. The pycnogonids were collected in August 1974, opisthobranchs in August and November 1974 and tubicolous polychaetes in December 1973. Occasionally a blennid fish (*Blennius steindachneri*) was found between the valves of dead oysters. Deposit of silt over the shells was noticed throughout the year. The growth of hydroids and algae facilitated a greater retention of silt on the shells.

Seasonal dominance

The dominance of the major fouling groups in different quarters of the year is shown in Table 1. Although the barnacles were present throughout the

TABLE 1. *Seasonal dominance of important fouling groups in pearl-culture farm at Veppalodai.*

	Season	Barnacles	Bryozoans	*Avicula* sp.	*Crassostrea* sp.
1973	Jan-Mar	Poor	Poor	Nil	Nil
	Apr-Jun	Moderate	Poor	Heavy	Nil
	Jul-Sep	Heavy	Poor	Nil	Nil
	Oct-Dec	Moderate	Moderate	Nil	Nil
1974	Jan-Mar	Poor	Heavy	Nil	Nil
	Apr-Jun	Moderate	Heavy	Poor	Heavy
	Jul-Sep	Heavy	Moderate	Nil	Poor
	Oct-Dec	Moderate	Poor	Nil	Nil

period of the study, they were in their highest numbers in July-September of both 1973 and 1974. The bryozoans started appearing in appreciable numbers in October-December and were generally dominant from January to June. An alternation of dominance by barnacles and bryozoans is evident from the table. The settlement of spat of *Avicula* and *Crassostrea* was confined to a narrow period, April-June.

Boring Organisms

Boring polychaetes, sponges, molluscs and isopods caused considerable damage to the shells of the pearl oysters. Polychaetes belonging to the families Syllinidae, Nereidae, Spionidae and Terebellidae were found to occur and, of these, the spionid *Polydora* sp. was the commonest borer. They caused simple as well as compound blisters on the inner sides of shells. The boring sponge *Cliona celata* was common in the farm, making widespread galleries in the shells. The molluscs *Lithophaga* sp. and *Martesia* sp. made fairly large holes and the isopod *Sphaeroma* sp. made burrows on the shells.

Effects of Fouling and Boring on Pearl Oysters

The fouling and boring communities apparently caused several deleterious effects which cumulatively affected the survival rate of the oysters in the farm. As stated before, barnacles stood out as the most significant ones, among the fouling organisms. The easily noticeable effect was physical interruption to opening and closing of the valves. The barnacles grew densely all over the valves (the maximum intensity noticed was 120 barnacles on a single valve) and, in many cases, cemented the margins of the valves together. Even when they were in small numbers, when they grew on the hinge line, they disabled the oysters from opening the shells. In both cases the oysters died eventually. The barnacles also gradually filled out the space between the meshes of the frame net which ultimately held the oysters tightly shut between the meshes. In addition to the above factors causative to the death of the oysters, the barnacles also indirectly caused recession in shell growth of the oysters as already reported (Alagarswami and Qasim 1973).

The growth of *Crassostrea* sp. on the pearl oysters caused effects similar to those of barnacles. The profuse growth of bryozoans and *Avicula vexillum* all over the frame nets reduced the free space of the nets and, thus, hampered the rate of flow of water. This might also have affected the efficiency of filtration of the pearl oysters.

The individual effects caused by other constituents of the fouling complex could not be made out. However, collectively, they also played a role in smothering the oysters. The peacrabs which are known to be parasitic on the clam *Meretrix casta* (Silas and Alagarswami 1967) were found inside the pearl oysters on a few occasions, but no damage to the tissues was noticed. The polyclad flat worms (Turbellaria) have been known to be carnivorous and preying upon the edible oysters (Miyazaki 1938, Yonge 1960). During the present study, although turbellarians were noticed among the fouling organisms, there was no instance when the worm was actually preying upon the oysters.

Among the boring organisms, *Polydora* sp. played a detrimental role. The worms bored into the shell both from the margins and the centre. Making a minute hole, they tunnelled through the horny periostracum and then into the prismatic and nacreous layers. This resulted in the formation of blisters on the inner surface of the shell, covered by the nacreous secretion of the oyster. The blisters were of various shapes — straight, wavy, sharply angled or U-like — depending on the course of perforation (Pl. I, Figs 5-7). In a few cases, the blisters erupted as tumour-like protrusions. Such protrusions were mostly found near the adductor impression (Pl. II, Fig. 1). Compound blisters were formed when the tunnels of two or more worms lay close together (Pl. II, Fig. 2).

The rate of infection by polychaetes was fairly high after about an year of cultivation of the oysters. Of 450 shells examined, 353 (78.4%) were with blisters. Among the infected shells, 28.3% carried single blisters and the rest more than one. The blisters were marginal in 24.1% of the cases. The rest had both marginal and centrally located blisters. The maximum number of blisters on a single valve was nine which were at different stages of development.

The numerous perforations caused by *Polydora* sp. weaken the shells and, in extreme cases, render them fragile. The compound and tumour-like blisters might put pressure on the pearl oyster's soft tissues by reducing the volume of the shell cavity. More important than this is the fact that the oyster secretes additional nacre for coating the blisters.

The boring sponge *Cliona celata* was another serious pest perforating the shells of oysters (Pl. II, Figs 3, 4). A total of 93 shells (20.7%), out of 450 shells examined, were found infected by the sponge in various degrees. The attack of *C. celata* started, in most of the specimens examined, near the umbo and spread sideways and downwards. In the early stages of attack, the pores were few and sparsely distributed. Subsequently, the shell was quickly penetrated and extensive galleries permeating the entire substance of the shell were formed, rendering it friable. This made the oyster susceptible to further damages, by polychaetes and other infections. The oyster secreted additional nacre to seal off the perforations, but it might eventually die due to physical exhaustion in the case of an extreme attack by the sponge. Mortality of edible oysters due to infection by the boring sponge has been reported by Korringa (1952).

The pholad *Martesia* was also found to cause serious damage to shells by making a number of holes on them. As many as eleven holes, made by *Martesia,* were found on a single oyster shell (Pl. II, Fig. 5). Only one case of boring by the mytilid *Lithophaga* was noticed during the study. The isopod *Sphaeroma* was found to make shallow grooves superficially on the shells eroding the periostracal and prismatic layers (Pl. II, Fig. 6).

Mortality of Pearl Oysters

The rate of mortality of pearl oysters was found to be related apparently to the intensity of fouling and the composition of the fouling complex. The data on the stock of oysters, percentage of mortality and quantitative estimates of

TABLE 2. *Fouling intensity and rate of mortality of pearl oysters in the farm at Veppalodai.*

Month	Duration in sea (days)	No. of oysters examined	Mortality of oysters %	Grades of fouling						Av. vol. of fouling per oyster (ml)	Av. barnacle load per oyster
				No. of nets	L	M	H	V.H	E.H		
1973											
Sep	30-60	382	11.0	8	7	1	..	..	..	3.3	9
	60-90	1023	25.3	24	4	10	3	3	4	10.6	55
	90-120	45	11.1	2	2	..	..	..	..	3.5	18
Oct	0-30	1034	0.9	26	26	..	..	..	..	1.3	2
Nov	60-90	85	14.1	4	1	3	..	..	..	5.5	18
Dec	30-60	745	18.5	22	7	8	2	3	2	9.2	32
1974											
Jan	30-60	76	2.6	2	2	..	..	..	..	2.2	9
	60-90	279	10.0	6	1	2	2	1	..	8.4	20
Feb	60-90	307	11.7	13	2	11	..	..	..	6.2	13
Mar	60-90	194	4.6	5	2	3	..	..	..	5.4	16
Apr	60-90	91	5.5	2	..	2	..	..	..	7.0	36
	90-120	154	9.1	4	..	2	2	..	..	7.8	15
	120-150	76	22.4	2	..	..	2	..	..	10.8	11
May	0-30	32	12.5	1	1	..	..	..	..	..	—
	30-60	76	6.6	2	..	2	..	..	..	7.2	—
Jun	30-60	110	5.5	4	3	1	..	..	..	3.0	—
	60-90	196	18.9	6	2	..	4	..	..	7.8	46
	90-120	226	20.4	13	3	6	3	1	..	6.4	20
	120-150	94	37.2	3	1	1	1	..	..	7.0	9
Jul	30-60	182	27.5	11	..	3	6	1	1	10.2	52
Aug	30-60	214	23.4	11	6	2	1	1	1	6.7	64
Sep	30-60	157	16.6	10	8	2	..	..	..	3.5	22
Oct	30-60	54	13.0	4	2	2	..	..	..	4.3	17
Nov	30-60	55	3.6	3	1	1	1	..	..	5.6	16
	60-90	192	3.1	6	3	3	..	..	..	4.3	18
Dec	30-60	229	Nil	9	8	1	..	..	..	2.8	37
	60-90	249	9.2	12	6	6	..	..	..	4.3	25

Explanations: L — low, M — medium, H — heavy, V.H. — very heavy, E.H — extremely heavy.

fouling for the period from September 1973 to December 1974 are presented in Table 2. The data have been grouped for different durations (blocks of 30 days) the oysters were in the farm between two successive cleanings. The period prior to September 1973 is not covered in the table for want of quantitative data on fouling. The monthly average values of volume of fouling, barnacle load and mortality are represented in Fig. 1.

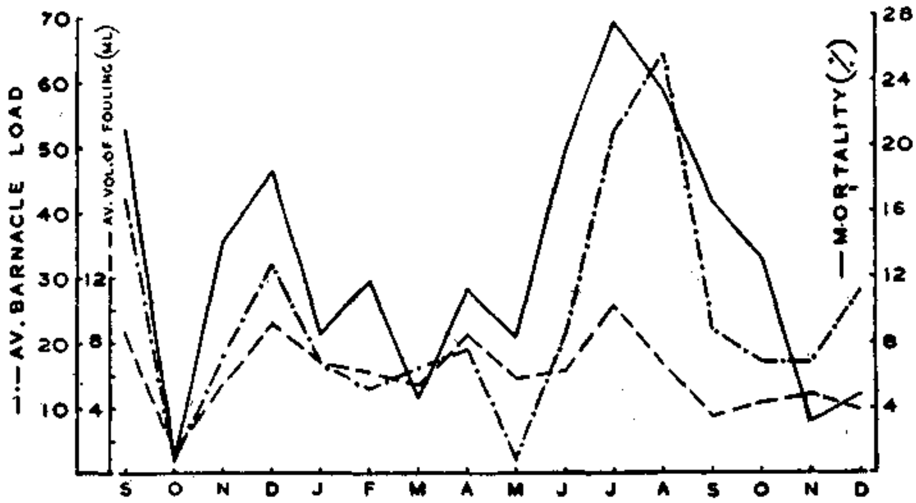


FIG. 1. Relationship among the barnacle load, volume of fouling and rate of mortality of pearl oysters observed at Veppalodai during the various months in 1973-74.

It can be seen from the table that the grades of fouling differed from net to net for the same duration of immersion and for different durations. The mortality was low when the grade of fouling was 'low', but increased with advances in grades, reaching high mortality rates at the 'heavy' to 'extremely heavy' grades of fouling. The lowest mortality of 0.9% was recorded in October 1973 and the highest mortality of 37.2% in June 1974 when the duration of immersion was 120-150 days. A seasonal trend in mortality was evident from the data. Two distinct peaks were noticed, one in December (1973) and the other in July (1974), which fell in the period of northeast and southwest monsoons respectively. However, the mortality in the northeast monsoon of 1974 was very low (it may be noted that this monsoon was a failure in this region). Generally the rate of mortality was low from January to May, the period that intervened the monsoons.

The influence of fouling on the rate of mortality of pearl oysters is clearly seen in Fig. 1. The fluctuations in the values of fouling, barnacle load and mortality correspond appreciably for the whole period except for the slight deviations noticed in February, March, November and December 1974. It appears that mortality of oysters is associated primarily with barnacles, and secondarily with bryozoans. Even a very heavy fouling of *Avicula*, as observed in April-May 1973, did not cause any significant mortality of oysters.

Although the above mentioned apparent relationships have been found between mortality of oysters and fouling in the farm, detailed investigations would be necessary to elucidate other factors which may also be responsible for the mortality. Decline in the condition of oyster may probably be due to a complex of factors involving, besides the fouling and boring organisms, bacterial and parasitic diseases, availability of and competition for food, suspension of silt and its effect on the efficiency of filtration of the oyster, clarity of water, etc. To what extent the mortality of pearl oysters is attributable to these different factors needs a careful study.

Remedial Measures

The observations presented above point to the inevitability of the problems of fouling, boring and mortality of oysters in pearl-culture farms. These problems could, however, be minimised by adopting appropriate control measures, the foremost among which would be periodic cleaning of the pearl oysters. In the Australian waters, the infection of edible oysters by *Polydora* was checked by exposing the oysters to the air and sun, when the worms were quickly killed (Yonge 1960). In Holland, a satisfactory treatment against *Polydora* was to expose the oysters either for 16 hours to fresh water or for 3 hours to a 0.5‰ solution of the ammonium salt of dinitro-orthocresol in sea water (Korringa 1951). For the control of *Cliona*, Korringa (1952) suggested bathing the infested oysters in fresh water for several hours (or in sea water containing a disinfectant). Loosanoff and Davis (1963) found pentachlorophenol at 1 ppm, formalin at 40 ppm and dichlorophene at 10 ppm useful in controlling certain bryozoans, ciliates and ascidians that sometimes infested trays or other containers of hatchery-reared juvenile molluscs. Besides frequent shell-cleaning operations, it is an urgent need to develop effective remedial measures against the fouling and boring organisms infesting the pearl oysters for achieving a higher survival rate.

Discussion

In the pearl-culture farms of Japan, fouling is severe from May to November (summer and autumn), although prevalent throughout the year. The fouling complex and dominant organisms differ from area to area and from station to station depending on their proximity to the open sea, and also from year to year (Yamamura *et al* 1969). In the Ago Bay, which is the most important area of pearl culture in Japan, the dominant fouling organisms are the tubicolous polychaetes, bryozoans, barnacles, ascidians, edible oysters and other bivalves (Yamamura *et al* 1969). At Tatoku in the Ago Bay, the polychaetes *Hydroides norvegicus* and *Dexiospira foraminosus*, and *Balanus amphitrite communis* formed the most numerous fouling organisms (Ota 1964). In the experiments at Veppalodai, barnacles (*Balanus amphitrite*) have been found to be the most serious pest, followed by the bryozoans and the seasonal setting of *Avicula vexillum* and *Crassostrea* sp. The tubicolous polychaetes (*Hydroides* sp.), unlike in the Japanese waters, have not been found to be significant, and they appeared in the farm only in December 1973. Fouling by the bivalves *Crassostrea gigas, Mytilus edulis* and *Anomia lischkeri* is also only seasonal at Tatoku during June-August, March-April and July-August respectively (Ota 1964). At Veppalodai, *Crassostrea* sp. was noticed during May-June, and *Avicula vexillum* during April-June. It is to be noted that culture of edible oysters and pearl oysters is done in the same areas in Japan (Alagarswami 1970) and hence settlement of spat of *C. gigas* in the pearl-culture farms is common during the spawning period.

Takemura and Okutani (1955), studying the fouling organisms on the pearl oyster *Pinctada maxima* from Arafura Sea, found tunicates and barnacles to be the dominant organisms. On the Sri Lanka pearl banks, Herdman (1906) found corals, barnacles and sponges adhering to the pearl shells, causing mechanically or through competition for food, injury and even death to the oysters. Kuriyan (1950) noticed a variety of organisms growing on the pearl-oyster cages at Krusadai and considered them a nuisance in many ways and as food rivals of the oysters. Mahadevan and Nayar (1968) observed profuse settlement of *Modiolus* spp. and discussed its possible role in the destruction of oyster population. The observations of the present authors showed that fouling on oysters was considerably more in the culture farm, having a depth of 4.5 m at about a distance of 1.5 km from the shore, than in the natural beds of the pearl oysters in the Gulf of Mannar which lie at a depth range of 15-25 m, at a distance of about 12 to 20 km from the shore. The turbid waters in the shallow area probably afforded ideal conditions for the settlement and growth of the numerous fouling organisms in the farm.

The boring polychaete *Polydora* has been widely held responsible for the great damages done to the edible-oyster populations in many parts of the world (Korringa 1951, 1952, Yonge 1960). *P. ciliata* has been reported to be a serious problem in pearl-culture farms in Japan. Mizumoto (1964) recorded 11 species of polychaetes and found *P. ciliata* significantly affecting the condition of pearl oysters; *P. ciliata, Terebella ehrenbergi* and *Syllis armillaris* made extensive blisters on the pearl-oyster shells. He also observed that in the case of *P. ciliata* only one worm was generally found in each blister (in 88.6% of the cases) and in the case of other genera two or more worms commonly occurred in the same blister (53.9-70.0% of the cases). It appears that the polychaete-borer problem is as severe in the present farm area as in the Japanese waters, and it needs a careful study.

The boring sponge *Cliona* is another widely distributed organism affecting the edible oysters in many parts of the world and destroying oyster beds in certain periods (Korringa 1951). Damages caused by *Cliona* to the pearl oyster *Pinctada margaritifera* in the Red Sea have been reported (FAO 1962). In the Japanese waters, however, the boring sponge does not appear to be a significant 'enemy' of the pearl oyster. Herdman (1905*a*) found 310 out of 400 pearl oysters examined in the Southwest Cheval paar (Sri Lanka pearl banks) infected with *Cliona margaritiferae* and observed that *Cliona* must undoubtedly be included among the more destructive agencies of pearl oysters. He found similar infection of the oysters in Modragam paars and attributed the increasing mortality rate of oysters to the combined boring effects of *C. margaritiferae, Polydora hornelli* and *Lithodomus sp.* (Herdman 1905*b*).

The incidence of molluscan borers *Martesia* and *Lithophaga,* which were found to make large direct holes on the pearl-oyster shells, was only about 3% and hence did not cause a serious problem. Herdman (1905*b*) noticed *Lithodomus* borings on the pearl oysters in the Sri Lanka waters. Takemura and Okutani (1955) found the boring bivalves *Lithophaga malaccana, L. teres* and *Rocellaria grandis* on *Pinctada maxima* in the Arafura Sea.

The intensive fouling noticed in the pearl-culture farm necessitated frequent cleaning operations. Cahn (1949) pointed out that periodical cleaning of the shells was the only practical defence against the fouling organisms. In the Japanese farms, shell cleaning is carried out from four to six times in the period from April to November (Wada 1973). The studies of Nishii (1961) and Nishii *et al* (1961) indicated that there may be some relation between the frequency of cleaning and the growth of pearls and that dense growth of edible oysters (*C. gigas*) and barnacles, when left uncleaned, might adversely affect the growth of the pearl oysters and the pearls. Wada (1973) reported that animals and seaweeds settling on the oysters and baskets inhibited the growth not only of the oysters but also of the pearls.

Heavy mortalities of pearl oysters have been reported from the Japanese waters due to red tides or marked changes in temperature and salinity of the bays or due to bacterial infection (Kotake and Miyawaki 1954, Cahn 1959). In the pearl-culture farm at Veppalodai, widespread blooms of the bluegreen alga, *Trichodesmium thiebautii,* were noticed in March-April and September 1973. However, the blooms did not seem to affect the oysters in the culture farm.

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